Free, friendly software uncomplicates power-supply design

FREE SOFTWARE FROM POWER-PRODUCTS VENDORS SAVES YOU TIME AND EFFORT WHEN YOU ARE CONFIGURING AND CHARACTERIZING POWER-SUPPLY DESIGNS.

Use this software to calculate total cost of ownership, reliability, and thermal performance for Ericsson's dc/dc converters.

POWER-SUPPLY DESIGN IS OFTEN A TRICKY PROPOSITION. Designing a power-supply IC (a boost or buck regulator, for example) into a system entails the prudent selection of several component values, as well as choosing the appropriate switch and rectifier elements. Most IC data sheets provide guidelines, equations, or graphs to aid in selection. Some companies, however, ease the design process by providing software that automatically selects components based on your system parameters, then characterizes the finished design. Component selection is not the only utility you can exploit with power-supply software; other programs allow you to calculate reliability, thermal performance, and even total cost of ownership (TCO) for particular supplies.

Selecting components is not as straightforward as you might imagine. It's not enough to know, for example, that your design needs a 300-μF capacitor. In many cases, you must also consider the maximum permissible equivalent series resistance (ESR) of the capacitor and, perhaps, connect several

capacitors in parallel to reduce the ESR. Inductive components are even trickier to select (**Reference 1**). Again, it's not enough to know that you need a 150-μH inductor; you also must take into account the inductor's series resistance and saturation characteristics. For National Semiconductor's family of Simple Switcher regulators, free design software makes component selection easy and painless.

AT A GLANCE

- ▷ Component selection for power-supply ICs can be tricky and time-consuming.
- ▷ Manual calculations for power-supply circuits can result in less-than-optimal designs.
- ▷ Power-supply-design software underscores the critical parameters of the external capacitors and inductive elements.
- ▷ You have access to both CD-ROM and online design software.

WINDOWS OR DOS?

National supplies three versions of Simple Switcher design software. For mouse aficionados, LM267X Made Simple Version 2.01 runs under Windows 3.1, 95, or NT 3.51 or greater. The software covers the LM2671 through LM-2679 family of step-down (buck) regulators, which provide maximum output currents of 0.5 to 5A. For those who still remember how to use a keyboard, two other programs run under MS-DOS 3.3 or later (as well as the various flavors of Windows). These programs use 521 kbytes of conventional RAM and 1 Mbyte of extended RAM. (Remember those quaint terms?) Switchers Made Simple Version 4.3 handles LM2594 through LM2599 buck regulators and LM2585 through LM2588 flyback/boost regulators. Switchers Made Simple Version 3.3 covers LM2574 through LM2576 buck regulators and LM1577/2577 flyback/boost regulators.

A quick experiment with LM267X Made Simple revealed that the program is simple, user-friendly, and effective. The CD-ROM from National provides an easy setup procedure and includes all related IC data sheets in .pdf (Adobe Acrobat Reader) format. The design program presents you with an array of "thermometer" toolbars. The toolbar for input voltage, for example, allows you to set the upper and lower limits of the input-voltage range. Error-handling is efficient: I tried to set an 11V lower input-voltage limit for a 12V-output step-down regulator, and the program gently reminded me to "Increase V_{IN} min first." I increased the V_{IN} to 20V, and the error message did not reappear.

A second thermometer allows you to set the output current, and a third one lets you set the minimum and maximum operating temperatures. I chose a 3A output current and a −25 to +85°C temperature range. With a mouse click on CALC, the routine computes a complete power-supply design. A print menu lets you select a print summary (**Figure 1**), a bill of materials (BOM), an all-parts list, an all-suppliers list, or all of the above. The software relieves you of performing many onerous manual calculations. The operating-point summary, for example, provides precise figures for efficiency; ripple; dynamic stability; and the thermal performance of the IC, including maximum junction temperature and junction-to-ambient thermal resistance.

In addition to doing the calculations for you, LM267X Made Simple vastly simplifies your process for selecting the necessary external components. **Figure 1** gives a succinct summary of the components; the BOM printout goes into considerable detail about the components, including recommended suppliers and every pertinent electrical parameter for the components. The all-parts list goes even deeper into the component selection and gives multiple sources as well as part numbers and electrical parameters for every component. The all-suppliers printout gives complete contact information for every recommended supplier. Finally, the schematic diagram of the computed design shows all component values, as well as the input-output parameters (**Figure 2**).

Switchers Made Simple Version 3.3, which National developed for MS-DOS before the advent of mouse mania, is an effective software tool for the company's LM157/2577 boost regulators. You use the keyboard (ah, the nostalgia) to enter the various parameters and their upper and lower limits. For the design in **Figure 3**, I entered a 4 to 6V input range, a 15V output voltage, a −25 to +85°C temperature range, and a 100-mA output current. This older program also provides effective error handling. I tried to enter a 5-mV maximum ripple, and a message told me the ripple voltage must equal or exceed 0.5% of the output voltage. Apparently, trying to obtain much lower ripple would result in outlandish capacitor values that would probably result in instability. A warning message cautions you to be wary of the capaci-

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Input Specifications

Designer's Input Specifications

 VinMin = 20 Volts
 VinMax = 25 Volts
 Vout   = 5 Volts Fixed
 Iout   = 3 Amps
 TaMin  = -25 °C
 TaMax  = 85 °C


Operating Values

 Vout             = 5 Volts
 Iout             = 3 Amps
 Osc. Freq. =     260 KHz
 Pout             = 15 Watts


Operating Point Summary at Vin = 25 Volts

 Efficiency       = 88.4 %
 Vout p-p         = 24.99 mVolts
 Cross Freq       = 19.5 KHz
 Phase Margin     = 94.09 Degrees
 IC Tj            = 88.2 °C
 IC Tja           = 4.2 °C/Watt
 Duty Cycle       = 21.8 %


Current Analysis

 Ic Ipeak         = 3.37 Amps
 Ic Ipeak(max)    = 7 Amps
 L Ipp            = 749.58 mAmps
 Iin Avg          = 1.94 Amps


Power Dissipation Analysis

 IC Pd            = 772.24 mWatts
 Diode Pd         = 890.94 mWatts
 L Pd             = 153 mWatts
 Cin Pd           = 154.69 mWatts


Parts List Summary

U1:          3 A            LM2676T-5.0         National Semiconductor Corporation
L:           22 µH          67148300            Schott Corporation
C in:        3x22 µF        TPSE226M035R0300    AVX Corporation
C out:       3x100 µF       TPSD107M010R0100    AVX Corporation
C boost:     10 nF          08055C103KAT        AVX Corporation
D1:          Schottky       IN5825              General Semiconductor, Inc.
HS:          0 °C/Watt
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Figure 1

The summary sheet for National Semiconductor's Simple Switcher software displays all the necessary circuit parameters and external-component values

tors' ESR at low temperatures.

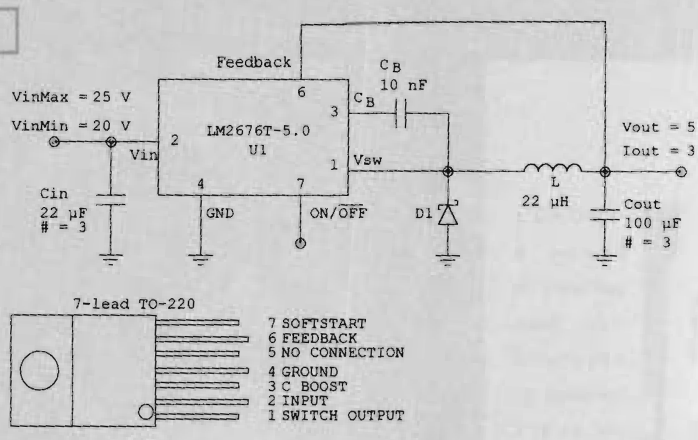
The summary sheet for the DOS-based software gives information similar to the information in the summary sheet of the Windows program but with somewhat less detail. For example, it provides component part numbers and suppliers (some sole-source, some multiple), ripple, stability parameters, and maximum junction temperature in the IC. It doesn't go so deeply into the components' electrical parameters; for example, the only capacitor parameters it offers are the capacitance values and the ESR of the output capacitor—a critical parameter, which, in this case, is 59 mΩ. National also supplies evaluation boards for Simple Switchers, so you can check empirical test results against the performance predictions of the simulation software.

Harris Semiconductor offers similar user-friendly simulation software for its HIP5020 step-down regulator with integrated power MOSFETs for switching and synchronous rectification. **Figure 4** shows the recommended configuration for the IC. The simulation program is easy to run; you simply enter the input-voltage range and the load current, and the software calculates the component values, switching frequency, thermal characteristics, and stability parameters. With an input range of 9 to 13V, for example, a 3.3V-output circuit switches at 208.3 kHz.

The HIP5020 simulation program returns exact (not EIA-standard) component values; for example, C_I=401 μF. However, when you click on C_I or any other component, you obtain a library of standard components with associated part numbers and vendors. An edit menu gives you several design options and utilities. For example, you can change the switching frequency. Higher frequencies reduce not only component size but also efficiency. If you click on Thermal, you obtain the thermal resistance of the design—in this case, 38°C/W—and a graph of thermal resistance versus the area of the ground plane connected to the various ground pins on the IC. A click on Compensation produces the circuit's transfer function:

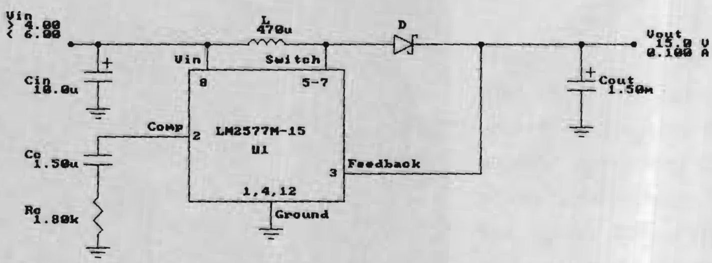
$$\frac{K}{s}=\frac{\frac{s}{2\pi f_Z}+1}{\frac{s}{2\pi f_P}+1},$$

Figure 2



A convenient schematic printout accompanies Figure 1's power-supply design; it shows both component values and package connections.

Figure 3



National's DOS-based Simple Switcher software also provides a handy printout of the calculated circuit.

where f_Z is the function's zero (1.89 kHz), f_P is the pole (29.7 kHz), and K is the gain factor (100.5 dB).

SWEDISH SOFTWARE TOOLS

Swedish multinational Ericsson packs its Power CD with materials that ease your power-supply selection and design-in task. The CD-ROM includes interactive analysis tools for considerations such as TCO, reliability, and thermal performance. The disk also includes Ericsson's complete product data book, cross-referenced application notes, and a power-module selector. You give the power-module selector details about the required performance you are seeking, and it automatically selects the appropriate product from the company's line. You can install the application on your hard drive, which requires 270 Mbytes of free space, or you can run it from the CD. The Power CD also includes Adobe Acrobat Reader.

The TCO Calculator accepts as inputs the following parameters, which relate to the cost of manufacturing and maintaining a power-supply system:

- production period,
- field-support period,
- interest rate,
- number of systems per year,
- operating hours per year,
- currency,
- cost of repair,
- ac/dc cost per watt,
- ac/dc-conversion efficiency,
- energy cost per kilowatthour, and
- model type.

The program calculates hardware, energy, and reliability costs and generates a TCO for the production program over its lifetime. A manual calculation using all the cost-generating parameters would be exceedingly complex and laborious. Ericsson's Thermal Calculator is equally comprehensive. After clicking on a power module from a menu, you enter:

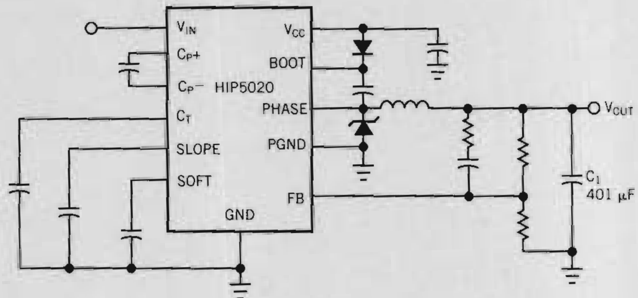
- board height,
- board width,
- board-to-board spacing,
- distance of the module from the bottom,
- total board power dissipation,
- module output power,
- ambient board temperature,

- air velocity, and
- type of pc board (number of layers).

When you click on Calculate, the program generates all important thermal parameters, such as case temperature, power loss to the ambient environment, substrate temperature, ambient temperature at the module, pin temperature, air velocity, and others. It also provides a graph of the thermal resistance of the module versus air velocity. Finally, it calculates the reliability of the design in failures-in-time (FIT) units. The Reliability Calculator provides more reliability information. You select the product family and enter the case temperature. The program calculates the reliability in both FIT and mean time between failures and provides a graph of FIT versus the case temperature.

All Ericsson calculating routines come with an associated .pdf-format tutorial-and-example section, which explains all parameters in detail. The .pdf documents give concrete examples of how to most effectively apply the programs. Finally, the Power CD contains some classy video clips and animation sequences—with voice-overs—that provide background on the company and its products, as well as technical information on the software and power-system design in general.

Figure 4



Computing the values of all the external components for Harris' HIP5020 would be an onerous task without the free software that the company makes available.

Figure 5

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*** NEWPORT COMPONENTS LIMITED
*** NME0505S DC-DC CONVERTER MODEL
*** 1W ISOLATED SINGLE OUTPUT DEVICE
*** NODE DESCRIPTION: VIN GND +VOUT 0V
.SUBCKT NME0505 1 2 3 4
DOUT 5 3 NCLD105
.MODEL NCLD105 D )IS = 1E-7 N=2.3 RS=2.8
+EG=1.11 XTI=3 BV=50 IBV = 25.9E-3 TT=2E-9)
COUT 3 1 0.5UF
E1 6 4 1 2 1.25
F1 1 2 VRPL -1.25
RNL 2 1 250
CIN 2 1 0.5UF
VRPL 5 6 DC 0 PULSE -0.68 0.02 0 0.25US 0.25US
4.5US
5US
CISOL 1 3 24PF
.ENDS NME0505
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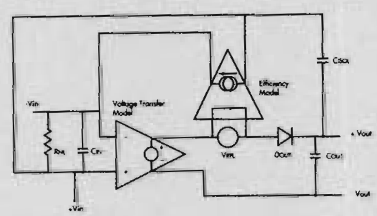

Spice models from Newport Components provide an accurate simulation of the company's power-supply modules.

SPICE MODELS

A CD-ROM from Newport Components Inc provides a complete .pdf-format data book for the company's dc/dc converters and inductive products. The CD also offers application notes on electromagnetic-compatibility design considerations and the design and application of transformers in power-supply systems. Spice models on the CD allow you to simulate the performance of inductors and two families of Newport dc/dc converters. **Figure 5** shows the Spice model and associated block diagram for the NME0505S Series of dc/dc converters, a family of 1W, single-output devices.

Newport maintains that dc/dc converters are notoriously difficult to simulate in Spice because oscillator circuits are inherently unstable in computer simulation. Spice simulations often settle into a static mode in which the circuit no longer oscillates, or the software takes too long to converge between iterations to be useful. The model in **Figure 5** uses a voltage-controlled voltage source to avoid oscillator and transformer requirements and to maintain input-output isolation. According to Newport, the diode is the most difficult part of the circuit to determine values for. The diode is a model in itself, taking account of the parameters governing resistance and saturation current to produce a load curve that matches the load curve of the diode's data sheet.

GET ON THE WEB

To obtain design software from some companies, you need Internet access. The InfoNavigator CD-ROM from Texas Instruments, for example, requires Netscape Navigator 4.x or Microsoft Internet Explorer 4.x to gain access to TI's Designer's Guide for the company's mixed-signal, analog, and power products. The Virtual Power Lab from Artesyn Technologies also requires one of these Web browsers. To obtain an overview of the Power Lab, you point your browser to www.artesyn.com.powerlab and then provide a user name and password. You obtain the simulation tool by clicking on an icon or the word "SimScope."

PowerLab and SimScope display a schematic that represents a typical application of Artesyn's BXB Series of dc/dc converters. You select the appropriate model from a pulldown menu and then click on any component to change the component's value. You then select a test and adjust the parameters from the Select Analysis Panel. A click on the Simulate button starts the simulation. Upon completion, you can click on any circuit node to observe voltage or current waveforms. You can click and drag inside the waveforms to zoom in on the image. You then have access to two analysis tools. First, you can obtain a graphical frequency-response analysis; then, you can click on the Bode Plot button to observe stability parameters.

The Virtual Power Lab is now in beta-test status. Artesyn requests that you use the simulation tool over a 30-day period for a total of 30 to 45 minutes, fill out a brief survey, and talk briefly with a member of the Virtual Power Lab development team. Your total time investment for the beta-testing effort should be approximately one hour.

The TopSwitch and TinySwitch Series of offline switching-power-supply ICs from Power Integrations Inc require a flyback transformer, plus several clamp-

ing, filtering, and rectification components. Designing the transformer is by no means a trivial task, so Power Integrations provides Excel spreadsheets to aid your design effort. To underscore the complexity of the transformer design, a 30-pg application note accompanies the spreadsheet and explains all the equations that the design uses (**Reference 2**). You can download the spreadsheets and the application-note .pdf file from Power Integrations' Web site, www.powerint.com.

Given the basic inputs (power, input voltage, and output voltage), the Power Integrations spreadsheets calculate elements of the transformer design, including wire gauge, core parameters, thickness, and other details. The programs also characterize the entire power-supply circuit. The spreadsheets use the maximum current limits of TopSwitch or TinySwitch to determine the worst-case transformer flux density under start-up or abnormal conditions. Power Integrations recommends that you keep the flux density at less than 4200 gauss. If Excel shows the density exceeding this figure, you reduce the value by increasing the number of turns, reducing the primary inductance, using a larger core, or using a combination of these measures.

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In the second half of this year, Power Integrations will offer a new tool based on Visual Basic. This tool promises to even further simplify power-supply design. The software uses one screen for basic input information, such as power, input, and output; a second screen to select the appropriate TopSwitch device; and a third screen to select the optimum transformer core. The company claims the software will offer you unlimited customization and delivers optimization routines for implementing the best design.

Recent power-supply ICs and modules simplify your system-design efforts; in an earlier era, you usually had to design your own supply. However, optimally using these devices is rarely a trivial undertaking. The various free software programs available from power-device manufacturers both simplify your design task and produce optimized designs.□

REFERENCES

1. Travis, Bill, "Living with losses: tips on using magnetic components," EDN, Jan 21, 1999, pg 77.

2. "TopSwitch Flyback Design Methodology," Application Note AN-16, Power Integrations Inc.

FOR MORE INFORMATION...

For free information on power-supply design software such as those programs described in this article, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use *EDN*'s InfoAccess. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

Artesyn Technologies
1-612-392-6587
www.artesyn.com
Circle No. 301

Ericsson Components AB
011-46-8-721-7500
www.energy.ericsson.se
Circle No. 302

Harris Semiconductor
1-800-442-7747
www.semi.harris.com
Circle No. 303

National Semiconductor Corp
1-800-272-9959
www.national.com/design/
Circle No. 304

Newport Components Inc
1-919-571-9405
www.newport-comps.com
Circle No. 305

Power Integrations Inc
1-408-523-9200
www.powerint.com
Circle No. 306

Texas Instruments Inc
1-972-644-5580
www.ti.com
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